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A COMPUTER SUBROUTINE FOR CALCULATING LOG VOLUMES BY THE INTERNATIONAL RULE

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ABSTRACT

Describes a FORTRAN computer subroutine for calculating board foot volume of sawlogs according to the International rule, assuming either 1/8-inch or 1/4-inch saw kerf.

Any association with the furtherance of use of the board foot as a unit of volume measurement should weigh heavily on the conscience of a responsible forest mensurationist. All the same, on the grounds that if one is going to use a bad procedure he should do it in a way that minimizes the undesirable effects, this Note presents a computer subroutine to calculate *accurately* the board foot volume of any reasonably sized log according to the assumptions of the International rule. The standard taper rate can be modified if the user desires.

The International log rule (Clark)[2] is a formula rule. Unlike some of the other formula rules, the International rule generates a discrete set of equations that contains a different equation for each log length. By contrast, the Doyle rule and similar rules that give inferior results are expressed by one formula in which log length is a variable. For example, the International rule (1/8-inch kerf) calculates board foot volume of a 4-foot stem segment as

$$V_4 = 0.22\, D_s^2 - 0.71\, D_s \qquad (1)$$

where

D_s = scaling diameter of the piece in inches

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[1] Mensurationist stationed in Moscow, Idaho, at the Forestry Sciences Laboratory, which is maintained in cooperation with the University of Idaho.

[2] J. F. Clark. Measurement of sawlogs. For. Quart. 4:79-93. 1906.

As a result, assuming one-half inch of taper per 4 feet of log length, the board foot volume of an 8-foot log is

$$\begin{aligned} V_8 &= 0.22\ D_s^2 \qquad\qquad - 0.71\ D_s \\ &\quad + 0.22\ (D_s + 0.5)^2 - 0.71\ (D_s + 0.5) \\ &= 0.44\ D_s^2 - 1.2\ D_s - 0.3 \end{aligned} \tag{2}$$

For a 12-foot log, board foot volume is

$$\begin{aligned} V_{12} &= 0.22\ D_s^2 \qquad\qquad - 0.71\ D_s \\ &\quad + 0.22\ (D_s + 0.5)^2 - 0.71\ (D_s + 0.5) \\ &\quad + 0.22\ (D_s + 1.0)^2 - 0.71\ (D_s + 1.0) \\ &= 0.66\ D_s^2 - 1.47\ D_s - 0.79 \end{aligned} \tag{3}$$

By adding still another 4-foot segment, Bruce and Schumacher[3] show the derivation of the volume formula for 16-foot logs. Obviously, one can derive formulae for 20-foot logs, 24-foot logs, and so on *ad absurdum*.

In general, the International 1/8-inch formula is

$$V = 0.22 \sum_{i=1}^{n} [D_s + t(i-1)]^2 - 0.71 \sum_{i=1}^{n} [D_s + t(i-1)] \tag{4}$$

where

D_s = the log's scaling diameter

n = the number of 4-foot sections in the log

t = taper (one-half inch per 4 feet is the standard International rule assumption)

By careful use of the inequality symbols in determining n, equation (4) can be considered a continuous function of log length. However, equation (4) is not continuously differentiable; that is, it is not a "smooth curve." Therefore, it is difficult to express the International rule as a single equation using scaling diameter and log length for use in a computer program. Nevertheless, some people have attained reasonable success by writing the coefficients of equations (1), (2), (3), and others, as functions of log length (Stage and others[4]). The coefficient of D_s^2 is linear with respect to length, and the coefficient of D_s has only one critical point, but the constant term in the equation requires at least cubic powers of log length for close approximation over an extended range of log lengths. This creates a risk of bad predictions (inherent in the use of polynomials) when extrapolating even a little way beyond the range of points to which the approximating equation was fitted.

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[3] Donald Bruce and Francis X. Schumacher. Forest Mensuration. McGraw-Hill Book Co., Inc., New York. 483 p., illus. 1950.

[4] Albert R. Stage, Richard C. Dodge, and James E. Brickell. NETVSL--a computer program for calculation of tree volumes with interior defect. U.S. For. Serv., Res. Pap. INT-51. 30 p., illus. 1968.

To avoid such risk, equation (4) has been programed in a computer subroutine which embodies the following procedures, all of which conform to the National Forest Log Scaling Handbook (FSH 2409.11):

1. If the log is less than 1 foot longer than an integer multiple of 4 feet, volume in the excess length is discarded at the small end of the log. Scaling diameter is moved toward the butt a distance equal to the excess length and increased by a small amount; this amount is equal to the product of taper rate and excess length. In short, trim allowance is taken off the small end of the log.

2. If the log is 1 or more but less than 4 feet longer than an integer multiple of 4 feet, volume in the portion of the additional length that is an integer number of feet is scaled and the rest discarded. The segment is scaled at the top end of the log after excess length has been discarded, and the remainder of the log is scaled in 4-foot segments.

3. The subroutine's default taper rate is one-half inch per 4 feet of log length. However, if diameter at a log's large end is measured and passed to subroutine JCLARK (see fig. 1), an average taper rate for the log will be determined and used to calculate board foot volume. One would expect that this default option probably would be used most often in order to conform to standard practice, but for logs having little or excessive taper the other option is available.

The variables in the calling sequence for JCLARK are as follows:

DS = diameter inside bark at the log's small end (scaling diameter).

DL = 0.0 if the default taper option (one-half inch) is to be used.
d.i.b. at the log's large end otherwise.

TL = total log length, including trim allowance.

KERF = 1 if 1/4-inch saw kerf is assumed.
0 if 1/8-inch saw kerf is assumed.

V = board foot volume returned to the calling program.

Log volumes computed using this subroutine are the same as those given in tables X and XI of the National Forest Log Scaling Handbook. In these tables, however, logs not having a length that is an integer multiple of 4 feet are assigned a volume by linear interpolation. JCLARK actually computes the volume of such logs. For an 18-foot log that has a scaling diameter of 120 inches, the difference between tabulated volume and calculated volume is 0.051 board foot. This is less than trivial except in those cases where rounding to the nearest 10 board feet might proceed in a different direction because of this slight difference. The program will not compute volumes for logs less than 4 feet long. Most log rules, including the International, were never intended for logs of extremely small diameter. Chipping headrigs were not widely used in 1906; thus, a user may get a negative answer if he attempts to calculate the board feet of 1 by 2 that can be produced from a 2.4-inch log.

JCLARK has been tested on an IBM 360/67, but it should operate on almost any system having a FORTRAN compiler available.

```
    SUBROUTINE JCLARK (DS,DL,TL,KERF,V)
C *-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
C THIS SUBROUTINE WAS WRITTEN BY J.E.BRICKELL OF THE U.S.FOREST SERVICE
C TO CALCULATE BOARD FOOT VOLUME OF SAWLOGS BY THE INTERNATIONAL RULE.
C VARIABLES IN THE CALLING SEQUENCE ARE:
C     DS   = LOG'S SCALING DIAMETER (INCHES)
C     DL   = DIB AT LOG'S LARGE END (INCHES) (0.0 IF 1/2 INCH TAPER)
C     TL   = TOTAL LOG LENGTH (FEET)
C     KERF >0 IF KERF ASSUMPTION IS 1/4 INCH
C     KERF <0, OR = 0, IF KERF ASSUMPTION IS 1/8 INCH
C     V    = LOG VOLUME RETURNED TO THE CALLING PROGRAM
C *-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
    V=0.0
C IF TOTAL LOG LENGTH IS LESS THAN FOUR FEET NO BOARD FOOT VOLUME WILL
C BE COMPUTED.
    IF(TL-4.0)10,1,1
C IF THE LOG'S LARGE END DIAMETER IS FURNISHED TO JCLARK A TAPER RATE
C WILL BE COMPUTED.  IF DL=0 THE STANDARD ASSUMPTION OF 1/2 INCH PER 4
C FEET OF LOG LENGTH WILL BE USED.
   1 IF(DL)3,3,2
   2 T=4.0*(DL-DS)/TL
    GO TO 4
   3 T=0.5
C THE FOLLOWING LOOP (THROUGH STATEMENT 5) FINDS OUT HOW MANY FULL 4
C FOOT SEGMENTS THE LOG CONTAINS.
   4 DO 5 I=1,20
    IF(TL-FLOAT(4*I))6,5,5
   5 CONTINUE
   6 L=I-1
    SL=FLOAT(4*L)
C THE FOLLOWING STATEMENT MOVES THE SCALING DIAMETER DOWN TO THE END OF
C THE 4 FOOT SEGMENTS AND INCREASES IT ACCORDING TO TAPER.
    D=DS+(T/4.0)*(TL-SL)
C THE FOLLOWING LOOP (THROUGH STATEMENT 7) FINDS OUT HOW MANY FULL FEET
C OF LENGTH ARE IN THE SEGMENT LESS THAN 4 FEET LONG.
    DO 7 I=1,4
    XI=FLOAT(I)
    IF(SL-TL+XI)7,7,8
   7 CONTINUE
C THE NEXT THREE STATEMENTS CALCULATE VOLUME IN THE 1, 2, OR 3 FOOT
C SEGMENT AT THE SMALL END OF THE LOG.
   8 XL=XI-1.0
    DEX=DS+(T/4.0)*(TL-SL-XL)
    VADD=0.055*XL*DEX*DEX-0.1775*XL*DEX
C THE FOLLOWING LOOP (THROUGH 9) CALCULATES VOLUME IN THE PORTION OF
C THE LOG CONTAINING WHOLE 4 FOOT SEGMENTS.
    DO 9 I=1,L
    DC=D+T*FLOAT(I-1)
   9 V=V+0.22*DC*DC-0.71*DC
    V=V+VADD
C IF 'KERF' IS GREATER THAN ZERO, INTERNATIONAL 1/8 INCH VOLUME AS
C COMPUTED ABOVE WILL BE CONVERTED TO INTERNATIONAL 1/4 INCH VOLUME.
    IF (KERF)10,10,11
  10 RETURN
  11 V=0.905*V
    RETURN
    END
```

Figure 1.

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